IN THE CLAIMS

The following is an amendment to, and a complete listing of the claims of the above-referenced application for patent that replaces all previous listing of claims in the application.

Listing of Claims:

1. (currently amended) A system for producing a cladding on a substrate, comprising:

a) a laser for processing materials and focusing means for directing and focusing a laser light beam from said laser onto a substrate surface, a substrate holder and positioning means for adjusting the position of the laser light beam and the substrate with respect to each other, and powder injection means for injecting powder onto said substrate surface;

b) image detection means for capturing images of an interaction region between said laser light beam and powder injected onto said substrate surface; and

c) a computer control means connected to said laser, said positioning means and said powder injection means, wherein said computer control means includes modeling means to model cladding growth by laser processing of powder[[,]] and extract from said model desired values for the pre-selected properties of the growing clad in real-time, and said computer control means including image processing means for [[the]] processing images of the interaction region between said laser light beam and the powder injected onto said substrate surface and extracting from said images values of pre-selected properties of [[the]] a growing clad in real-time, said computer control means including processing means to compare said extracted values of said pre-selected properties of the growing clad in real-time to desired values of said pre-selected properties of the growing clad produced by ~~an effective model of cladding growth~~

~~by laser processing of powder, said computer control means responsively adjusting parameters of the laser light beam, powder feedrate and positioning means based on differences between the extracted values of the pre-selected properties of the growing clad in real-time and the desired values of the pre-selected properties of the growing clad~~ the model of cladding growth by laser processing of powder, and wherein said image processing means includes pattern recognition processing means to extract the pre-selected properties of a growing clad in real-time from images captured by the image detection means, said computer control means including intelligent process controller means interfaced to said laser, said intelligent process controller being a fuzzy logic controller including fuzzy logic membership functions, an inference engine and a defuzzification module, wherein said fuzzy logic membership functions are utilized to fuzzify the difference between first input signals, which are said extracted values of the pre-selected properties of the growing clad in real-time extracted by said pattern recognition processing means, and second input signals which are the desired values of the pre-selected properties of the growing clad, and wherein the inference engine combines the fuzzified difference between said first and second input signals, and wherein the defuzzification module defuzzifies outputs of the inference engine to convert them back into quantitative values, said quantitative values being output from the intelligent process controller means and used to adjust parameters of said laser light beam, the positioning means and said powder injection means to give the desired values of the pre-selected properties of the clad.

2. (cancelled)

3. (cancelled)

4. (currently amended) The system according to claim [[3]] 1 wherein said pre-selected properties of the growing clad in real-time include dimensions of the clad, roughness of the clad and rate of solidification of the clad.

5. (currently amended) The system according to claim 1 wherein said [[laser]] parameters of the laser light beam include beam size of the laser light beam focused onto the substrate surface and energy of the laser light beam.

6. (currently amended) The system according to claim 5 wherein said laser is a pulsed laser and wherein said [[laser]] parameters of the laser light beam include pulse rate of the pulsed laser and pulse duration of each laser light pulse produced by the pulsed laser.

7. (currently amended) The system according to claim [[2]] 1 wherein said pattern recognition processing means extracts a border of a bright area between molten and non-molten regions on the surface in the images detected by the image detection means, and from the border calculating dimensions and solid/liquid interface angle (α) [[of]] between a melt pool ~~at the solid/liquid interface between the melted surface and powder~~ and ~~solid~~ surface, and from the solid/liquid interface angle (α), determining the rate of solidification.

8. (currently amended) The system according to claim 7 wherein said dimensions of the clad calculated by the pattern recognition ~~software~~ processing means includes height of the clad, and wherein said intelligent process controller means adjusts the parameters of the laser light beam, substrate holder velocity, powder ~~feedrate~~ feed rate and orientation of powder stream directed onto the surface of the substrate in order to maintain a selected height of the melt pool, a selected angle α and ~~substantially~~ suppress fluctuations in said height.

9. (currently amended) The system according to claim [[2]] <u>1</u> wherein said positioning means is connected to said substrate holder for moving said substrate holder with respect to said laser beam.

10. (original) The system according to claim 9 wherein said positioning means includes speed adjustment means for adjusting a speed of the substrate holder with respect to the laser light beam.

11. (original) The system according to claim 9 wherein said focusing means for directing and focusing a laser light beam includes adjustable focusing optics for adjusting a beam size of the laser light beam on the surface of the substrate.

12. (currently amended) The system according to claim 1 wherein said laser <u>light beam</u> is a continuous wave (CW) or pulsed laser beam.

13. (original) The system according to claim 1 wherein said image detection means is at least two charge coupled device (CCD) cameras positioned in a pre-selected orientation with respect to each other and the substrate surface.

14. (original) The system according to claim 1 wherein said image detection means is a plurality of charge coupled device (CCD) cameras disposed about said substrate for capturing a plurality of images.

15. (currently amended) A method for producing a cladding on a substrate, comprising:

a) injecting powder onto a surface of a substrate and directing and focusing a laser light beam having effective laser light beam parameters onto the substrate surface;

b) capturing images of an interaction region between the laser light beam and the powder injected onto the substrate surface using at least two image detectors; and

c) processing the captured images of the interaction region between the laser light beam and the powder injected onto the substrate surface and extracting from the images pre-selected properties of [[the]] a clad in real-time by merging of the images received from the at least two image detectors using an effective morphological structuring element neighborhood method, and to obtain therefrom two matrices, one of the matrices being a boundary matrix representing [[the clad's]] boundaries of the chad on the substrate and another matrix being an overlap matrix representing the overlap between the at least two images captured by the at least two image detectors, and calculating a difference between the extracted pre-selected properties to desired values of the pre-selected properties produced by an effective model of cladding growth by laser processing of powder, and using the difference to adjust processing parameters to ~~substantially~~ give the [[desired]] real time values of the pre-selected properties of the clad.

16. (currently amended) The method according to claim 15 ~~wherein the step of capturing images of an interaction region between the laser light beam and the powder injected onto the substrate surface includes capturing the images with at least two image detectors, and~~ wherein the step of processing the captured images includes producing a binary black and white image in which black indicates one of the melting and solid areas of the clad and the substrate respectively and the white areas indicates the other.

17. (currently amended) The method according to claim 16 wherein the step of processing the captured images includes projection of the at least two mages received from the at least two image detectors onto a reference plane using a transformation matrix that is obtained based on orientations of the at least two image detectors with respect to the reference plane and a clad trajectory.

18. (currently amended) The method according to claim [[19]] 17 wherein the reference plane is the ~~substrate~~ plane of the surface of the substrate.

19. (cancelled)

20. (currently amended) The method according to claim [[19]]16 wherein the step of extracting the pre-selected properties of the clad in real time includes determination of ~~the clad's~~ dimensions of the chad using the boundary and overlap matrices, wherein a width of the clad is determined using the boundary matrix and the combination of the boundary and overlap matrices and the binary images are used to extract [[the]]height and angle (α) of a melt pool at [[the]] a solid/liquid interface between the ~~melted~~ melting area of the surface and powder and the solid area of the surface.

21. (original) The method according to claim 20 wherein the width of the clad is calculated based on the number of bright pixels in a pre-selected column of the boundary matrix.

22. (currently amended) The method according to claim 20 wherein an uncalibrated height of the clad for any corresponding column in the boundary and overlap matrices is extracted by counting a number of pixels between the clad's boundary and the overlap ~~boundary~~ matrices.

23. (original) The method according to claim 22 wherein an actual height of the clad is obtained using a scaling factor of the images and angles of the image detectors with respect to the substrate to scale the uncalibrated height of the clad.

24. (currently amended) The method according to claim 20 wherein angle (α) of [[a]] the melt pool at the solid/liquid interface is obtained directly from the binary images captured by the at least two image detectors, and wherein the angle between [[the]] a border of a bright area in a tail of the melting pool seen by each image detector and a reference horizontal line along with a relative orientation of the image detectors and a clad trajectory is used to extract the solid/liquid interface angle α.

25. (original) The method according to claim 20 including calibrating the at least two image detectors using an image of a standard with known dimensions, wherein after calibrating the at least two image detectors calculating a corresponding location of any pixel in the matrices.

26. (currently amended) The method according to claim [[20]] 15 wherein the step of calculating a difference between the extracted pre-selected properties to preferred values of the pre-selected properties produced by an effective model of cladding growth by laser processing of powder includes fuzzifying the difference between the extracted pre-selected properties of [[the]] a growing clad in real-time and the desired values of [[the]] pre-selected properties of the growing clad, combining the fuzzified difference between the extracted pre-selected properties and the desired values of the pre-selected properties of the growing clad using ~~the said~~ ~~interference~~ an inference engine ~~and set rules producing~~ to produce fuzzified outputs, and ~~defuzzifies~~ defuzzifying the fuzzified outputs ~~producing~~ to produce quantitative values, ~~sending the quantitative values to the laser,~~

~~positioning device and powder feeder for adjusting the laser parameters, substrate position and powder feed parameters~~ and using said quantitative values to adjust said processing parameters to give the desired values of the pre-selected properties of the clad in real time.

27. (currently amended) The method according to claim 26 wherein the processing parameters include parameters of the laser light beam, substrate holder velocity, powder ~~feedrate~~ feed rate and orientation of powder stream directed onto the surface of the substrate.

28. (original) The method according to claim 27 wherein the parameters of the laser light beam include beam size of the laser light beam focused onto the substrate surface and energy of the laser light beam.

29. (original) The method according to claim [[29]] 27 wherein the laser light beam is a pulsed laser light beam and wherein the laser parameters include pulse rate of the laser and pulse duration of each laser light pulse.

30. (original) The method according to claim 15 wherein the pre-selected properties of the clad include height, width, rate of solidification and clad roughness.

31. (currently amended) The method according to claim 27 wherein the step of adjusting the processing parameters to give desired real time clad properties includes adjusting parameters of the laser light beam, substrate holder velocity, powder ~~feedrate~~ feed rate and orientation of powder stream directed onto the surface of the substrate in order to maintain a pre-selected height of the melt pool and ~~substantially~~ suppress fluctuations in said height.

32. (cancelled)

33. (cancelled)

34. (currently amended) The method according to claim [[32]] 53 wherein the substrate is mild steel.

35. (currently amended) The method according to claim [[32]] 53 wherein the specified bulk composition is about Fe:20 wt % Al.

36. (currently amended) The method according to claim [[32]] 53 wherein the laser beam is a pulsed laser beam.

37. (New) A method for producing a cladding on a substrate, comprising:

a) injecting powder onto a surface of a substrate and directing and focusing a laser light beam onto the substrate surface;

b) capturing images of an interaction region between the laser light beam and the powder injected onto the substrate surface; and

c) processing the captured images of the interaction region between the laser light beam and the powder injected onto the substrate surface and extracting from the images pre-selected properties of a growing clad in real-time, and calculating a difference between the extracted pre-selected properties to desired values of the pre-selected properties produced by an effective model of cladding growth by laser processing of powder, the step of calculating the difference between the extracted pre-selected properties to preferred values of the pre-selected properties produced by an effective model of cladding growth by laser processing of powder including fuzzifying the difference between the extracted pre-selected properties of the growing clad in real-time and the desired values of the pre-selected properties of the growing clad, combining the fuzzified difference between the extracted pre-selected properties and the desired values

of the pre-selected properties of the growing clad using an inference engine to produce fuzzified outputs, and defuzzifying the fuzzified outputs to produce quantitative values, and using said quantitative values to adjust processing parameters to give the desired values of the pre-selected properties of the clad.

38. (New) The method according to claim 37 wherein the step of processing the captured images includes merging of images received from at least two image detectors using an effective morphological structuring element neighborhood method and obtaining therefrom two matrices, one of the matrices being a boundary matrix representing the clad's boundaries on the substrate and another matrix being an overlap matrix representing an overlap between the two images captured by the at least two image detectors.

39. (New) The method according to claim 38 wherein the step of processing the captured images includes producing a binary black and white image in which black indicates one of melting and solid areas of the clad and the substrate respectively and white indicates the other.

40. (New) The method according to claim 39 wherein the step of processing the captured images includes projection of the images received from the at least two image detectors onto a reference plane using a transformation matrix that is obtained based on orientations of the at least two image detectors with respect to the reference plane.

41. (New) The method according to claim 40 wherein the reference plane is the plane of the surface of the substrate.

42. (New) The method according to claim 39 wherein the step of extracting the pre-selected properties of the clad in real time includes determination of the

clad's dimensions using the boundary and overlap matrices, wherein a width of the clad is determined using the boundary matrix and the combination of the boundary and overlap matrices and the binary images are used to extract height and angle (α) of a melt pool at a solid/liquid interface between the melting area of the surface and powder and the solid area of the surface.

43. (New) The method according to claim 42 wherein the width of the clad is calculated based on the number of bright pixels in a pre-selected column of the boundary matrix.

44. (New) The method according to claim 42 wherein an uncalibrated height of the clad for any corresponding column in the boundary and overlap matrices is extracted by counting a number of pixels between the clad's boundary and the overlap matrices.

45. (New) The method according to claim 44 wherein an actual height of the clad is obtained using a scaling factor of the images and angles of the image detectors with respect to the surface of the substrate to scale the uncalibrated height of the clad.

46. (New) The method according to claim 42 wherein angle (α) of the melt pool at the solid/liquid interface is obtained directly from the binary images captured by the at least two image detectors, and wherein the angle between a border of a bright area in a tail of the melt pool seen by each image detector and a reference horizontal line along with a relative orientation of the image detectors and a clad trajectory is used to extract the solid/liquid interface angle α .

47. (New) The method according to claim 42 including calibrating the at least two image detectors using an image of a standard with known dimensions, wherein after calibrating the at least two image detectors calculating a corresponding location of any pixel in the matrices.

48. (New) The method according to claim 38 wherein the processing parameters include parameters of the laser light beam, substrate holder velocity, powder feed rate and orientation of powder stream directed onto the surface of the substrate.

49. (New) The method according to claim 48 wherein the parameters of the laser light beam include beam size of the laser light beam focused onto the substrate surface and energy of the laser light beam.

50. (New) The method according to claim 49 wherein the laser light beam is a pulsed laser light beam and wherein the laser parameters include pulse rate of the laser and pulse duration of each laser light pulse.

51. (New) The method according to claim 38 wherein the pre-selected properties of the clad include height, width, rate of solidification and clad roughness.

52. (New) The method according to claim 48 wherein the step of adjusting the processing parameters to give desired real time clad properties includes adjusting parameters of the laser light beam, substrate holder velocity, powder feed rate and orientation of powder stream directed onto the surface of the substrate in order to maintain a pre-selected height of the melt pool and suppress fluctuations in said height.

53. (New) The method according to claim 15 wherein said powder is a mixture of Fe and Al powders, pre-mixed to a specified bulk composition and wherein said clad is an iron-aluminum clad.

54. (New) The apparatus according to claim 1 wherein said image detection means includes at least two image detectors, and wherein said image processing means includes means for projecting images received from said at least two image detectors onto a reference plane using a transformation matrix that is obtained based on orientations of the at least two image detectors with respect to a reference plane and a clad trajectory.